

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants: M. ARIFUKU, et al.

Serial No.: 10/541,380

Filed: JULY 6, 2005

Title: CIRCUIT CONNECTING MATERIAL, FILM-FORM CIRCUIT CONNECTING MATERIAL USING THE SAME, CIRCUIT MEMBER CONNECTING STRUCTURE AND METHOD OF MANUFACTURING 5THE SAME

Group AU: 1793
Examiner: Kallambella M. Vijayakumar
Confirm. No.: 8734

DECLARATION UNDER 37 CFR 1.132

Commissioner for Patents
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SIR:

I, Motohiro ARIFUKU, a citizen of Japan, residing at Chikusei-shi, Ibaraki, Japan, DECLARE THAT:

1. I graduated from the University of Tokyo, with a Master's Degree in Chemistry.
2. I have been employed by Hitachi Chemical Co., Ltd., since 1995, where I have been engaged in research and development relating to anisotropic conductive films.
3. I am one of the named inventors in Application No. 10/541,380, filed July 6, 2005 (hereinafter "the above-identified application").
4. In order to show the unexpectedly better results in reduced connection resistance and increased bonding strength achieved by the circuit connecting material of the present invention, having conductive particles with a hardness as in the claims of the above-identified application, and wherein the circuit connecting

material has a storage elastic modulus and a mean coefficient of thermal expansion as in all of the claims of the above-identified application, the following experiments were conducted either by me or under my supervision.

5. Preparation of Materials:

a. Phenoxy resin 2:

Phenoxy resin 2 was synthesized from bisphenol A type epoxy resin and 4,4'-(9-fluorenylidene) diphenol. The weight average molecular weight of Phenoxy resin 2 measured by gel permeation chromatography (GPC) in terms of polystyrene was 40,000.

b. Acrylic rubber 1:

Acrylic rubber 1 was synthesized from Butyl acrylate (50 parts by weight), Ethyl acrylate (30 parts by weight), Acrylonitrile (20 parts by weight) and Glycidyl methacrylate (2 parts by weight). The molecular weight of Acrylic rubber 1 was 850,000. Acrylic rubber 1 (125 g) was soluted by ethyl acetate (400 g), and a 30% solution was prepared.

c. Conductive Particles No. 18:

Core bodies of Conductive Particles No. 18 were obtained by mixing tetramethylolmethane tetraacrylate, divinylbenzene and a styrene monomer, and performing suspension polymerization using benzoyl peroxide as a polymerization initiator. The core bodies were plated with an electroless Ni plating and Conductive Particles No. 18 were obtained. The mean particles size of the core body was 5 μm . The Ni plating thickness was 100 nm. The hardness of the conductive particles was 2.9549 GPa (320 kgf/mm²).

6. Film-form circuit connecting material:

a. Additional Example 1:

A film-form circuit connecting material of Additional Example 1 was produced like Example 1, except that Phenoxy resin 2 was used instead of the phenoxy resin of Example 1.

b. Additional Example 2:

A film-form circuit connecting material of Additional Example 2 was produced like Example 1, except that 15 g of a phenoxy resin, 35 g of Acrylic rubber 1 and 50 g of Novacure were added, instead of adding 30 g of a phenoxy resin, 30 g of bisphenol A type epoxy resin and 40 g of Novacure, to the solution in Example 1.

c. Additional Reference Example 1:

A film-form circuit connecting material of Additional Reference Example 1 was produced like Example 1, except that Conductive Particles No. 18 were used instead of Conductive Particles No. 1.

d. Additional Comparative Example 1:

A film-form circuit connecting material of Additional Comparative Example 1 was produced like Example 1, except that silica glass was additionally included.

e. Additional Comparative Example 2:

A film-form circuit connecting material of Additional Comparative Example 2 was produced like Example 1, except that 15 g of a phenoxy resin, 55 g of Acrylic rubber 1 and 30 g of Novacure were added, instead of adding 30 g of a phenoxy resin, 30 g of bisphenol A type epoxy resin and 40 g of Novacure, to the solution in Example 1.

7. Circuit member connecting structure 1:

Circuit member connecting structure 1 was produced by the same way described in [0132] to [0134] of the specification of the above-identified application, from the film-form circuit connecting material described in Paragraph No. 6 herein.

8. Bonding Strength, Storage Elastic Modulus and Mean Coefficient of Thermal Expansion:

The bonding strengths were measured by a 90° peel test with a delaminating polyimide film by 50 mm/min. The bonding strengths after 1,000 hours in an environment of 80°C, 95% RH were also measured. And the storage elastic modulus at 40°C and the mean coefficient of thermal expansion were measured. The results are shown in Table I. Table I also shows results of Examples 1-6 and Comparative Examples 1-10 of the specification of the above-identified application.

Table I

		Bonding Strength (N/cm)				storage elastic modulus at 40 °C (GPa)	mean coefficient of thermal expansion (ppm/°C)		
		Two-layer FPC		Three layer FPC					
		initial	After 1000 hr in 80°C,95%RH	initial	After 1000 hr in 80°C,95%RH				
Example	1	7.2	2.1	9.8	4.4	1.8	60		
	2	7.4	2.4	9.2	4.6				
	3	7.8	3.4	10.4	4.3				
	4	6.9	3.1	9.3	4.8				
	5	8.1	2.8	9.2	4.1				
	6	8.7	4.3	10.3	5.6				
Comparative Example	1	6.8	2.4	9.1	5.1	1.8	60		
	2	7.2	2.5	9.4	4.6				
	3	7.6	2.3	9.1	4.6				
	4	8.1	2.8	9.8	4.2				
	5	7.6	2.1	10.2	4.8				
	6	7.5	2.6	9.5	4.1				
	7	7.8	3	9.7	4.3				
	8	7.4	2.7	9.8	4.7				
	9	7.3	2.4	9.9	4.5				
	10	7.1	2.3	9.1	4.2				
Additional Example	1	6.5	1.7	8.4	3.8	2.9	58		
	2	8.9	5.6	10.3	5.9	0.8	110		
Additional Reference Example	1	7.4	2.2	9.6	4.1	1.8	60		
Additional Comparative Example	1	4.1	-	5.8	-	4.3	44		
	2	5.8	2.8	6.1	4	0.4	220		

9. In Additional Comparative Example 1, Bonding Strength could not be measured because the bonding agent had peeled away. This is because the storage elastic modulus at 40°C (4.3 GPa) exceeded 3 GPa and internal stress increased.

10. Measurement of Connection Resistance and Counting of Conductive Particles:

The resistance values of the circuit were measured and the numbers of conductive particles that were present on the respective circuit electrodes were counted by the same way described in [0135] and [0136] of the specification of the above-identified application. The results are shown in Table II.

Table II

Film-form circuit connecting material		Connecting structure using two-layer FPC			Connecting structure using three-layer FPC		
		Connection resistance (Ω)		Number of conductive particles on connected electrodes (number)	Connection resistance (Ω)		Number of conductive particles on connected electrodes (number)
		initial	After 1000 hr in 80°C, 95%RH		initial	After 1000 hr in 80°C, 95%RH	
Additional Example	1	0.9	1.7	7	1.98	2.55	7
	2	1.4	2.5	7	2.6	3.88	7
Additional Reference Example	1	1.8	3.9	8	2.8	5.4	8
Additional Comparative Example	1	0.7	1.1	6	1.6	2.33	6
	2	2.1	4.5	8	3.1	6.32	8

11. In Additional Reference Example 1, the connection resistances were higher than that of the Additional Examples 1 and 2. This is because the hardness of Conductive Particles No. 18 was lower than 4.4413 GPa.

12. In Additional Comparative Example 2, the connection resistances were higher than that of the Additional Examples 1 and 2. This is because the mean coefficient of thermal expansion was higher than 200 ppm/ $^{\circ}$ C.

13. Circuit member connecting structure 2:

Circuit member connecting structure 2 was produced by the same way described in [0141] to [0143] of the specification of the above-identified application, from the film-form circuit connecting material of the Additional Examples, Additional Reference Example and Additional Comparative Examples.

14. Measurement of Connection Resistance and Counting of Conductive Particles:

The resistance values of the circuit were measured and the number of conductive particles that were present on the respective circuit electrodes were counted by the same was described in [0144] and [0145] of the specification of the above-identified application. The results are shown in Table III.

Table III

Film-form circuit connecting material		Connection resistance (Ω)		Number of conductive particles on connected electrodes (number)
		initial	After 1000 hr in 80°C, 95%RH	
Additional Example	1	1	0.2	6
	2	1	0.9	6
Additional Reference Example	1	11	1.2	5
Additional Comparative Example	1	1	0.1	5
	2	210	>3	5

15. In Additional Reference Example 1, the connection resistances were higher than that of the Additional Examples 1 and 2. This is because the hardness of Conductive Particles No. 18 was lower than 4.4413 GPa.

16. In Additional Comparative Example 2, the connection resistances were higher than that of the Additional Examples 1 and 2. This is because the mean coefficient of thermal expansion was higher than 200 ppm/ $^{\circ}$ C.

17. As shown above, the use of the circuit connecting material of the present invention makes it possible to achieve a sufficient reduction in the connection resistance and a sufficient bonding strength, and these effects are unexpected from the cited references.

The undersigned hereby declares that all statements made herein of his knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine, or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

2014/5/24
Date

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